JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

RE-ORDER NO. 61-476

PHYSICAL PARAMETERS INSTRUMENTATION FOR SURVEYOR

INTERFACE AND DESCRIPTIVE INFORMATION

TEXACO INC.
RESEARCH AND TECHNICAL DEPARTMENT
EXPLORATION AND PRODUCTION RESEARCH DIVISION
BELLAIRE, TEXAS

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under NASw-6

INTRODUCTION

Attached is the latest descriptive and interface information available for the Surveyor instrumentation to measure physical parameters on and beneath the lunar surface. This is a modernization and rearrangement of the information contained in the document prepared on January 17, 1961.

Owing to the present uncertainties as to the grouping or arrangement of the surface instrumentation, no overall description of the placement and/or operation of the surface facilities is included. Each instrument is treated as a separate unit with no detailed information given as to its possible inclusion on subassemblies to be extended from the main spacecraft.

Exact placement of the various surface instruments should be fixed (arbitrarily if necessary) by agreement among Jet Propulsion Laboratory, Hughes Aircraft Company, and Texaco Inc. as soon as possible. This is necessary if firm designs are to be prepared and fabricated for laboratory breadboard models of the surface units within the allotted time.

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CONTENTS

TEMPERATURE
Surface

Location: On S/C or surface package.

a. Description of Method: A total radiation pyrometer (or pyrometers) will be used to measure the temperature of the lunar surface. The difficulties encountered in using thermocouples, thermistors, and resistance thermometers to obtain surface temperatures directly have made this necessary.

The pyrometer may be mounted either directly on the spacecraft or on a subsystem extended from it.

b. Dimensions of Sub-Assembly: 1 in. diameter, 3 in. long (radiometer and preamplifier).

c. Weight of Radiometer and Preamplifier: 6 oz.

d. Special Environmental Requirements: Coatings to limit upper temperature level may be required.

e. Required Orientation: Radiometer should view unshaded portion of lunar surface at least 2 ft. from radiometer.

f. Required Knowledge of Orientation: Viewing unshaded portion of surface with TV view of surface surveyed.

g. Required Manipulation: None.

h. Sample Preparation Requirements: None.

i. Time per Operating Cycle: Continuous sensor operation with sampling as specified below.

j. Number of Operating Periods: Sample once per hour for one month with continuous sampling during day/night and night/day transitions (3 hrs. centered around sunrise and sunset).

k. Operating Power: Power to operate thermistor sensing device and temperature sensors associated with radiometer. Fifteen (15) MA at 15 volts per detector - 225 millivolts watts. Two (2) temperature detectors required per radiometer.

l. Data Output:

(a) Thermocouple outputs - 0.3 to 0.8 millivolts per degree K. 150 millivolts is total range and there is no bias. Recovery of data on earth to 0.3 millivolts is required (4 outputs). Measurement range: 120 to 400°K.

(b) Radiation pyrometer outputs - 20 millivolts per degree K after preamplification. Dynamic ranges - 2 - 8 volts DC. Two (2) outputs required.

m. Real Time Data Requirements: None.

n. Other Requirements: Temperature reference to tie all thermocouple reference junctions. Absolute temperature of reference to be known to ±0.5°K. S/C contractor to provide this reference within the S/C.

NOTE: In many instances where a thermocouple has been specified as a means of monitoring an instrument temperature, a thermistor may be employed. Thermocouples need only be employed in those situations where the heating effect of the measuring current required for a thermistor is itself sufficient to disturb the temperature.

THERMAL DIFFUSIVITY

Surface

Location: On surface of moon off leg of S/C or other convenient appendage.

a. Description of Method: At surface, the thermal diffusivity is to be deduced from the change in temperature experienced within a region of known geometry as a result of abruptly altering the quantity of heat energy entering the surface by radiation. This alteration can result from an infrared source (i.e., a lamp) or by use of a shield of known surface emissivity abruptly interrupting incoming solar radiation. The temperature at center of the area of altered radiation must be followed as a function of time for about an hour, and this temperature history can then be used to estimate thermal diffusivity.

b. Dimensions of Sub-Assembly:

(a) Shield 12 in. diameter, held within 2 in. of lunar surface.

(b) Light source held 2 ft. above surface, 40° angle of illumination.

c. Weight:

(a) Shield plus radiometer - 12 oz.

(b) Light source and radiometer - 12 oz.

d. Special Environmental Requirements: None.

e. Required Orientation:

(a) Shield - on unshaded portion of lunar surface.

(b) Light - radiometer should view central part of illuminated area of lunar surface.

f. Required Knowledge of Orientation: TV view of surface to be involved in either shield or light source determinations.

g. Required Manipulation:

(a) Shield - should be rapidly (less than 2 sec.) positioned or unfolded on an unshaded area of the lunar surface.

(b) Light source - none.

h. Sample Preparation Requirements: None.

i. Time per Operating Cycle:

(a) Shield - 1 hr.

(b) Light source - 3 to 4 hrs. Light source on for 1 to 2 hrs. Continuous sensor operation for 1 hr. prior to turning light on and 1 hr. after turning light off.

j. Number of Operating Periods:

(a) Shield - to be determined.

(b) Light source - 1 to 3, depending upon power available at night.

k. Operating Power:

(a) Shield - power to place or unfold shield and operate radiometer and temperature sensor on (or in) shield.

(b) Light source - 10 to 80 watts for 1 to 2 hrs. to operate light plus power to operate radiometer.

l. Data Output: See TEMPERATURE, Surface. In addition to radiometer outputs, shield temperature must be known.

m. Real Time Data Requirements: None.

n. Other Requirements: None.

MAGNETIC SUSCEPTIBILITY
Surface

Location: Sub-assembly.

a. Description of Method: The most feasible method for measuring the in-situ magnetic susceptibility, which is simply related to the permeability, appears to be one which makes use of the principle that the mutual inductance between two coils varies with the susceptibility of the surrounding media. It is proposed that a comparative measurement of the mutual inductance between the two coils with the coils away from the lunar surface and placed on the lunar surface be made. The change in the mutual inductance is proportional to the magnetic susceptibility of the material near the lunar surface. One method of measuring the change in mutual inductance is to use a Carey-Foster bridge arrangement with a third bucking coil placed near the original two coils.

b. Dimensions of Subsystem: 12 in. in diameter by 6 in. high (see drawing of sub-assembly).

c. Weight: 3 lbs.

d. Special Environmental Requirements: The boom that lowers the package to the surface must be of a non-magnetic nature; epoxy, etc. DC magnetic field to be less than .25 gauss, AC magnetic field to be less than .001 gauss.

e. Required Orientation: Sub-assembly must be located so that it is 5 ft. from main spacecraft or any large metalic body. The device should be located either in sunlight or shadow, i.e., no partial shadows should exist while readings are being made.

f. Required Knowledge of Orientation: None.

g. Required Manipulation: For each magnetic susceptibility determination the sub-assembly must first be raised at least 3 ft. above the lunar surface to obtain a zero reading. The sub-assembly is then lowered until a designated face rests upon the lunar surface. The magnetic susceptibility reading is then taken immediately.

h. Sample Preparation Requirements: None.

i. Time per Operating Cycle: Time to balance bridge and record resistance. S/C contractor must specify time required to balance bridge.

j. Number of Operating Periods per Lunar Day: Take a reading with sub-assembly in vacuum, i.e., raised at least 3 ft. from surface, lower sub-assembly to surface as fast as possible after this reading and repeat. This sequence should be repeated at least 5 times during lunar day and 5 times during lunar night.

k. Operating Power:

(a) 1000 cycles/sec. ±25%, but known well enough to be compatible with data output.

(b) Power input - current through transmitter coils will be determined by the sensitivity of the instrument used to detect the null.

(c) Distortion of AC to bridge to be less than 0.5%.

(d) Input impedance to 12 in. coils and bridge 1500 ohm. DC resistance of transmitter coils 250 ohm. DC resistance of receiver coil 50 ohm.

l. Data Output: For the bucking coil recommended, a change in mutual inductance of 0.1 microhenry per 10^{-6} cgs units change of susceptibility. Range 400 - 5500 microhenries, measurement range - 10 to 50,000 10^{-6} cgs units. Required accuracy on earth ±25%.

m. Real Time Data Output: None.

n. Other Requirements:

(a) Temperature of sub-assembly should be known to within ±2°C.

(b) Surface magnetic susceptibility coils must be open circuited during resistivity measurement.

(c) Surface resistivity coil must be open circuited during surface magnetic susceptibility measurements.

MAGNETIC SUSCEPTIBILITY
(Alternate Method) Surface Unit

Location: Off leg of main spacecraft.

a. Description of Method: The most feasible method for measuring the in-situ magnetic susceptibility, which is simply related to the permeability, appears to be one which makes use of the principle that the mutual inductance between two coils varies with the susceptibility of the surrounding media. It is proposed that a comparative measurement of the mutual inductance between the two coils with the coils away from the lunar surface and placed on the lunar surface be made. The change in the mutual inductance is proportional to the magnetic susceptibility of the material near the lunar surface. One method of measuring the change in mutual inductance is to use a Carey-Foster bridge arrangement.

b. Dimensions of Device: 3 in. in diameter by 1/2 in. thick.

c. Weight: 4 oz.

d. Special Environmental Requirements: None.

e. Required Orientation: Device should be at least 8 in. from any metal object when in either of its two positions.

f. Required Knowledge of Orientation: None.

g. Required Manipulation: Alignment and placement of device on the lunar surface with face of coils conforming to lunar surface as close as possible. When a reading is desired the device will be raised from the surface at least 8 in. and recorded; immediately after this recording it should be dropped to the surface and a repeat reading performed.

h. Sample Preparation Requirements: None.

i. Time per Operating Cycle: Time to balance bridge and record resistance. S/C contractor must specify time required to balance bridge.

j. Number of Operating Periods per Lunar Day: A repeat of g. above at least 5 times during lunar day and 5 times during lunar night.

k. Operating Power:

(a) 1000 cycles/sec. ±25%, but known well enough to be compatible with data output.

(b) Power input - current through transmitter coils will be determined by the instrument used to detect the null, i.e., power required from the bridge output to detect the null will vary accordingly with the sensitivity of null finding mechanism.

(c) Distortion of AC to bridge to be less than 0.5%.

(d) Input impedance to transmitter coils and bridge 400 ohms. DC resistance of transmitter coils 40 ohms. DC resistance of receiver coils 40 ohms.

l. Data Output: Range - 10 to 50,000 x 10^{-6} cgs. units.

m. Real Time Data Requirements: None.

n. Other Requirements:

(a) Temperature of device must be known to within ±2°C.

(b) A suitable position for mounting the opposing set of coils needed with the surface coils and also the sub-surface coils must be furnished by the S/C contractor. This set of coils can be located on a leg, or within the S/C, provided there will be no change in their mutual inductance due to moving metalic objects or stray fields.

RESISTIVITY
Surface

Location: Lowered to surface from leg of S/C or other position such as sub-assembly.

a. Description of Method: Resistivity to be measured by placing a coil a known distance from the surface and measuring the Q (figure of merit).

b. Dimensions of Apparatus: Approximately 12 in. in diameter by 1/4 in. thickness. This coil is located on a sub-assembly with the surface magnetic susceptibility coils.

c. Weight of Coil and Coil Holder: 6 oz.

d. Special Environmental Requirements: None.

e. Required Orientation: Device should be at least 5 ft. from S/C or any large metalic object when in either of its two positions.

f. Required Knowledge of Orientation: See Required Manipulation.

g. Required Manipulation: For each Q measurement the sub-assembly must be raised at least 3 ft. above the lunar surface to obtain a zero reading. The sub-assembly is then lowered until a designated face rests upon the lunar surface. The Q reading is then repeated immediately.

h. Sample Preparation Requirements: None.

i. Time per Operating Cycle: Time required by S/C instruments to measure Q and inductance of coil.

j. Number of Operating Periods per Lunar Day: Take a reading with sub-assembly in vacuum, i.e., raised at least 3 ft. from surface, lower sub-assembly to surface as fast as possible after this reading and repeat. This sequence should be repeated at least 5 times during lunar day and 5 times during lunar night.

k. Operating Power: To be determined when S/C manufacturer decides what instrument will be used to measure Q and inductance.

l. Data Output: Measurement range 10^{+1} to 10^{+16} ohm cm.

m. Real Time Data Requirements: None.

n. Other Requirements:

(a) Temperature of sub-assembly should be known to within ±2°C.

(b) Surface magnetic susceptibility coils must be open circuited during resistivity measurement.

(c) Surface resistivity coil must be open circuited during surface magnetic susceptibility measurements.

DENSITY
Surface

Location: May be located on leg of spacecraft or other positions.

a. Description of Method: Density is to be measured using the gamma-gamma logging technique. The intensity of gamma radiation transmitted by a known thickness of material from a source emitting radiation of known intensity and character is measured using a GM counter. The density is linearly related to the log of the transmitted intensity. Background levels are monitored by separate GM counter shielded from source.

b. Dimensions of Apparatus: 27.5 cm. long by 8.1 cm. diameter.

c. Weight of Density Device and Monitor: 40 oz. for density, 2 oz. for monitor.

d. Special Environmental Requirements: Radiation environment allowed at density and monitor geiger counters - maximum of 500 gamma quanta per cm^2 per second and 15 electrons (energy > 1 MEV) per cm^2 per second.

e. Required Orientation: Source shield should be located such that a minimum of direct gamma radiation is transmitted to monitor located at least 4 ft. from density measuring device. Density device must be located such that no scatterers

about the source will cause an error in density measurements. Density device is oriented such that with device in rested position, window faces lunar surface.

f. Required Knowledge of Orientation: A TV view of surface emplacement area both before and after emplacement of sub-assembly.

g. Required Manipulation: The monitor must be exposed to the surface of which the density is desired. The density device must be lowered to the surface.

h. Sample Preparation Requirements: None.

i. Time per Operating Cycle: Density 3 minutes, monitor 3 minutes.

j. Number of Operating Periods: 10 periods; all when temperature is within limits of counter reliability.

k. Operating Power:

(a) 10 microamps drain (log + monitor).

(b) 800 volts DC of regulated power.

Range - 800 ±100 volts DC.

Tolerance - 2% of operating voltage.

Ripple - tolerance depends on supply. At 60 cycles, 10 volts ripple is acceptable. In the KC range ripple should be less than 0.1 volt.

(c) Output impedance of power supply to be under 1000 ohms.

(d) Power to release mechanism for placement of density measuring device to be determined by S/C manufacturer.

l. Data Output: 2 volt negative pulse 50 microsecond duration - 50 to 1000 cps, load impedance 500K ohm, range is 100K to 1 megohm.
Measuring range - 0.5 to 4 gm/cc.

m. Real Time Data Requirements: None.

n. Other Requirements: Source - 40 millicuries of cesium 137. Range + 20 millicuries to -10 millicuries.

HARDNESS
Surface Only

Location: Penetrometers to be mounted either on S/C or on a separate sub-assembly to be placed on lunar surface.

a. Description of Method: The hardness of the immediate surface is to be investigated by recorded the acceleration-time-history of a dropped weight. The weight will contain an accelerometer, will be allowed to drop a few inches in essentially free fall, will have a cone shaped impact point, and will be held in approximately vertical alignment while falling. The acceleration-time-history (or wave shape of the acceleration upon impact with the surface) will be used to empirically analyze the hardness characteristics of the surface. The depth of investigation will range between approximately 1/2 in. for soft materials such as loose sand, and a few thousands of an inch for very hard material. Three separate units are to be used to examine three different locations.

b. Dimensions of Hardness Unit: 5 in. overall height by 1-1/4 in. diameter, but with 3/4 in. additional radius on one side and near the top for release mechanism.

c. Weight: 3 oz. each unit, total of 9 oz. (these units could serve as legs for the sub-assembly).

d. Special Environmental Requirements: None, if high impedance accelerometer such as Endevco, Model 2242, requiring amplifier input impedance > 100 megohm, is used.

e. Required Orientation: Vertical alignment within 15°, with respect to gravitational vertical.

f. Required Knowledge of Orientation: Preferable to have TV picture of area of test.

g. Required Manipulation: Each unit to be placed against lunar surface on a designated face, particular location on surface not critical. Electrical release mechanism for each unit to be operated, one at a time (or in unison if recording system allows).

h. Sample Preparation Requirements: None.

i. Time per Operating Cycle: 1 sec. for each of 3 drops.

j. Number of Operating Periods per Lunar Day: 1 (including 3 drops).

k. Operating Power: 28 volts DC applied for 2 sec. (one time for each unit) to operate release mechanism, 0.1 amp current.

l. Data Output: The wave shape of the signal generated in the accelerometer after release and upon impact on the lunar surface is to be reproduced and studied on earth and compared empirically on earth with those generated by a similar

device on known materials. Total time of the acceleration pulse (during impact) would range between 14 milliseconds (in soft sand) and 0.1 millisecond in material with Moh hardness of 6 or 7. Peak amplitudes may vary between 0.2 volts and 10 volts. These figures may vary considerably depending on accelerometer used, mass of weight, height of drop, and hardness and shape of cone tip. The above figures are projected for use with Endevco Accelerometer Model 2242, 3 in. drop with lunar gravity, drop weight of 50 grams (on earth), and cone tip of hardened 4130 steel with 60° included angle.

The accelerometer can be used with several feet of cable, however, a high impedance amplifier must be used, input impedance > 100 meg., preferably 500 meg. This high impedance can be partially accomplished by use of a resistance divider network, since relatively high signal voltages will be available. (Specially designed low-impedance accelerometers which will operate in the environmental temperatures may possibly be available; this has not been ascertained. The Endevco Model 2215 is ideal except for environmental temperature limitations.

m. Real Time Data Requirements: None. Data storage is acceptable if wave shape can later be reproduced accurately.

n. Other Requirements: None.

ACOUSTIC VELOCITY

Surface

Location: Explosive source off one leg of S/C. First acoustic detector off another leg of S/C. Second acoustic detector placed on lunar surface 5 to 10 ft. away from S/C.

a. Description of Method: The compressional wave velocity is the most feasible velocity to measure. Accurate measurements of the arrival time (first arrival) of the waves generated by a pulsed acoustic source (DuPont X-311B Mild Electric Initiator) are made at two acoustic detectors or receivers (Hall-Sears, Inc., Standard HS-J, 27 cps moving-coil geophones), with the source and detectors placed in known orientations and positions.

b. Dimensions: Source and associated shield - 4-1/2 in. diameter by 2-1/4 in. overall height. Geophone, 2 units, will have 1 in. diameter, 1-1/4 in. height, but with base having 3 points as feet, making overall height 1-5/8 in. and overall diameter 1-5/8 in.

c. Weight: Source and shield - 12 oz. Detectors, 2 at 3 oz. each, total - 6 oz.

d. Special Environmental Requirements: Acoustic source; explosive sources to be used will function satisfactorily after

storage at 350°F for 2 hrs., 300°F for 6 hrs., 250°F for 24 hrs., or 185°F for over 6 weeks. This will require special attention in thermal radiation requirements on the source holder and shield.

e. Required Orientation: Acoustic source, first detector and second detector to be placed in contact with lunar surface, at known locations, and each with a designated face against surface. Let $\vec{r}_1$ = directed distance from source to first detector and $\vec{r}_2$ = directed distance from source to second detector; then $5^1 \leq |\vec{r}_1| \leq 10^1$, and 5 ft. $\leq |\vec{r}_2| - |\vec{r}_1| \leq$ 10 ft. preferable, however, that detectors both be on a radius line from source.

f. Required Knowledge of Orientation:

(a) Orientation of source, first detector, and second detector with local surface and relative to local vertical to be known to within 15 degrees.

(b) Separation Distances:

(1) Second detector and source, between 10 and 15 ft., known to ±5%.

(2) First detector and source, between 5 and 10 ft., known to ±5%.

(c) TV view of surface emplacement area for source, first detector, and second detector, both before and after emplacement.

g. Required Manipulation:

(a) Placement of second detector on surface with designated face in contact with surface.

(b) Placement of first detector on surface with designated face in contact with surface. If this unit is to be mounted on one of the S/C legs, this placement might be accomplished by release of spring mechanism designed to press the detector against the lunar surface and also to act as an acoustic decoupling mechanism.

(c) Placement of acoustic source and shield with designated face against surface.

h. Sample Preparation Requirements: None.

i. Time per Operating Cycle: 1 sec. (starting at time of detonation of acoustic source).

j. Number of Operating Periods per Lunar Day: 6.

k. Operating Power: Assurance of detonation of explosive source during lunar night will require that a minimum of 20 amperes of current be applied, and that this current be available for at least 10 milliseconds. Resistance of the explosive firing element (without attached wires) will be 0.44 ±0.25 ohm. A "time break" signal will be supplied by breaking a wire at time of detonation. Some slight current (depending on circuit used) will be required. No power is required for acoustic detectors.

1. Data Output: Time of travel from source to first detector, and from source to second detector is of primary concern. Due to the wide range of materials and conditions, it will be necessary to record the wave shape of signals from each of the two detectors, the relative times of the source "time break" and the two signal waves shapes being of major importance. Amplitude measurements would be of less concern. The two signal channels should have identical frequency response and sensitivity.

Geophone signals may have peak amplitudes as low as 10 microvolt and as high as 1 millivolt (or higher, amplitudes higher than 1 millivolt may necessarily have to be clipped or limited). Coil resistance of geophone approximately 300 ohms. Amplifier input circuit should contain a 300 ohm resistor for geophone damping. Impedance matching and transformer can be used with step-up turns ratio, such as 1:50 or 1:100, capable of passing frequencies 50 cps to 5 KC. Noise-equivalent on the input (at geophone) should be no more than 1 microvolt peak-to-peak.

Geophone signals should be recorded for at least 0.1 sec. immediately following time of application of firing current to each of the multi-shot explosives. Recording time up to 1 sec. would be desirable. A "time break" pulse, triggered by the break of a wire near the explosive, should be added to each geophone signal channel. This pulse should not "blank" the geophone channel for more than 50 microseconds

(in real time). Detection of the "time break" pulse (relative to the timing of the geophone signal) should be accurate to ±5 microseconds.

Measurement range - velocity of 300 to 20,000 ft/sec., or travel times (to the first geophone if at 5 ft.) of 16.7 milliseconds to 0.25 millisecond (33.3 to 0.5 millisecond for a geophone at 10 ft. from source). Accuracy of velocity determinations to be made from data received on earth to be ±10% in lower velocity range and ±20% in upper range.

m. Real Time Data Requirement: Data storage is acceptable if accurate time measurements are included. Time accuracy required for acoustic measurement is ±5 microseconds on time of firing acoustic source, and 12.5 microseconds uncertainty in the difference between arrival times at the two sensors.

n. Other Requirements:

(a) Acoustic decoupling (through spacecraft) of second detector, first detector, and acoustic source.

(b) All equipment acoustically quiet during velocity measurement. Noise with frequencies within the band pass of the acoustic velocity measurements (50 cycles to 5 KC) must be avoided.

TEMPERATURE

Subsurface

Location: See general description of subsurface logging sonde.

a. Description of Method: A total radiation pyrometer will be used to measure temperature of the sidewall of the bored bole. The pyrometer will be the same as that used for surface measurements with the addition of a conical mirror to restrict the view of the radiometer to a portion of the sidewall. The difficulties encountered in using thermocouples, thermistors, and resistance thermometers to obtain downhole temperatures directly have made this necessary.

The unit is mounted near the bottom of the sonde.

b. Dimensions of Sub-Assembly: 1" diameter and 3" long (radiometer and preamplifier).

c. Weight of Radiometer and Preamplifier: 6 oz.

d. Special Environmental Requirements: None, however, measurement is questionable under conditions other than clean, competent hole.

e. Required Orientation: None.

f. Required Knowledge of Orientation: None.

g. Required Manipulation: Temperature measurement should immediately follow movement of sonde downward to new location.

h. Sample Preparation Requirements: None.

i. Time per Operating Cycle: Continuous sensor operation with sampling as specified below.

j. Number of Operating Periods: Refer to overall description of operation of downhole sonde.

k. Operating Power: Power to operate thermistor sensing device and temperature sensors associated with radiometer. 15 MA. at 15 volts per detector - 225 millivolts. Two (2) temperature detectors required per radiometer.

l. Data Output:

(a) Thermocouple outputs - 0.3 to 0.8 millivolts per degree K. 150 millivolts is total range and there is no bias. Recovery of data on earth to 0.3 millivolts is required (5 outputs). Measurement range - 120 to 400°K.

(b) Radiation pyrometer outputs - 20 millivolts per degree K after preamplification. Dynamic ranges; 2 - 8 volts DC. Two (2) outputs required.

m. Real Time Data Requirements: None.

n. Other Requirements: Temperature reference to tie all thermocouples reference junctions. Absolute temperature of reference to be known to ±0.5°K. S/C contractor to provide this reference within the S/C.

NOTE: In many instances where a thermocouple has been specified as a means of monitoring an instrument temperature, a thermistor may be employed. Thermocouples need only be employed in those situations where the heating effect of the measuring current required for a thermistor is itself sufficient to disturb the temperature.

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THERMAL DIFFUSIVITY

Subsurface

Location: See general description of subsurface logging sonde.

a. Description of Method: This device will be a small blackbody into which power is dissipated at constant rate. The temperature rise of this blackbody as a function of time is a complex function of the power input, borehole geometry, sonde materials, and the thermal diffusivity and thermal conductivity of the media adjacent to the borehole. This instrument must be empirically calibrated to account for all variables except the diffusivity and conductivity of the medium. Having eliminated all variables other than the thermal diffusivity and conductivity, the temperature rise data can be interpreted to give values to these quantities.

b. Dimensions of Sub-Assembly: Less than 7/8" diameter, less than 2" long. Geometry to be determined.

c. Weight: 4 oz.

d. Special Environmental Requirements: None.

e. Required Orientation: None.

f. Required Knowledge of Orientation: None.

g. Sample Preparation Requirements: None.

h. Time per Operating Cycle: Minimum operating period - 120 minutes.

i. Operating Power: On the order of 1 watt. It may be advisable in order to cover a range of possible thermal diffusivities of the surrounding media to have optional power 1/2 to 1 to 2 watts available. Use of this device is still under investigation.

j. Number of Operating Periods: Refer to overall operation procedure for the downhole sonde.

k. Data Output: Temperature sensor output vs. time, and power input to the heat source.

l. Real Time Data Requirements: None.

m. Other Requirements: None.

NOTE: In many instances where a thermocouple has been specified as a means of monitoring an instrument temperature, a thermistor may be employed. Thermocouples need only be employed in those situations where the heating effect of the measuring current required for a thermistor is itself sufficient to disturb the temperature.

MAGNETIC SUSCEPTIBILITY

Subsurface

Location: Subsurface Logging Sonde.

a. Description of Method: The technique proposed, which has been demonstrated experimentally is to measure the change in mutual inductance of two coils between the conditions of air (or vacuum) and within the hole. A mutual inductance bridge of the Carey-Foster type is the recommended method of measuring this change in the mutual inductance. The difference in the mutual inductance under the two conditions is proportional to the magnetic susceptibility of the lunar material through which the hole penetrates.

b. Dimensions of Sub-Assembly: Refer to description of subsurface logging sonde.

c. Weight of Magnetic Susceptibility Measuring Device: Refer to description of subsurface logging sonde.

d. Special Environmental Requirements: None.

e. Required Orientation: The logging sonde must be decentralized in the borehole.

f. Required Knowledge of Orientation: When a measurement is taken the borehole diameter must be known from data taken with the caliper.

g. Required Manipulation: See description of subsurface logging sonde.

h. Sample Preparation Requirements: None.

i. Time per Operating Cycle: Time required for null detecting instruments to function and record the readings.

j. Number of Operating Periods per Lunar Day: Refer to description of subsurface logging sonde.

k. Operating Power:

(a) 1000 cycles/sec. ±25%, but known well enough to be compatible with data output.

(b) Power input - current through transmitter coils will be determined by the instrument used to detect the null, i.e., power required from the bridge output to detect null will vary accordingly with the sensitivity of null finding mechanism.

(c) Distortion of AC to bridge to be less than 0.5%.

(d) Input impedance to transmitter coils and bridge: 400 ohms. DC resistance of transmitter coils: 40 Ohms. DC resistance of receiver coils: 40 ohms.

l. Data Output: Measurement range 10 to 50,000 x 10^{-6} cgs units. Required accuracy on earth ±25%.

m. Real Time Data Output: None.

n. Other Requirements:

(a) Temperature of logging sonde must be known to within ±2°C.

(b) A suitable position for mounting the opposing set of coils needed with the subsurface coils and also the surface coils (alternate) must be furnished by the S/C manufacturer. This set of coils can be located on a leg or within the S/C provided there will be no change in their mutual inductance due to moving metalic objects or stray fields.

CALIPER
Subsurface

Location: Subsurface sonde.

a. Description of Method: Hole size is to be measured by using the decentralizer spring position in the borehole to change the position of a slide wire on a poteneometer.

b. Dimension of Sub-Assembly: See general description of subsurface logging sonde.

c. Weight of Device: See general description of subsurface logging sonde.

d. Special Environmental Requirements: None.

e. Required Orientation: None.

f. Required Knowledge of Orientation: See general description of subsurface logging sonde.

g. Required Manipulation: See general description of subsurface logging sonde.

h. Time per Operating Cycle: Time required to measure potenteometer resistance.

i. Sample Preparation Requirements: None.

j. Number of Operating Periods: See general description of subsurface logging sonde.

k. Operating Power:

(a) To be determined by type instrument used by S/C manufacturer to measure resistance.

(b) Impedance approximately 1000 ohms.

l. Data Output: A measure of resistance.

m. Real Time Data Output: None.

n. Other Requirements: None.

RESISTIVITY
Subsurface

Location: See general description of subsurface logging sonde.

a. Description: Resistivity is to be measured by inserting a coil into the borehole and measuring the Q (figure of merit). There will also be a change in the inductance of the coil due to the permeability of the surrounding media. Separation of the two is feasible and the magnetic susceptibility as determined by the magnetic susceptibility experiment can be checked.

b. Dimensions of Apparatus: See general description of subsurface logging sonde.

c. Weight of Coil: 2 oz.

d. Special Environmental Requirements: None.

e. Knowledge of Orientation: None.

f. Required Knowledge of Orientation: When a measurement is taken the borehole diameter must be known from data taken from caliper.

g. Required Manipulation: See general description of subsurface logging sonde.

h. Sample Preparation Time: None.

i. Time per Operating Cycle: Time required to measure Q and inductance of coil.

j. Number of Operating Periods per Lunar Day: Refer to general description of subsurface logging sonde.

k. Operating Power: To be determined when S/C manufacturer decides what instrument will be used to measure Q and inductance.

l. Data Output: Measurement range 10^{+1} to 10^{+16} ohm cm.

m. Real Time Data Requirements: None.

n. Other Requirements: Temperature of coil should be known to within ±2°C.

DENSITY
Subsurface

Location: Subsurface logging sonde.

a. Description of Method: Utilizes the method of gamma-gamma logging wherein a partially shielded radiation source is placed a known distance from a partially shielded GM counter. The logarithm of the detected gamma radiation is inversely related to the density of the lunar material.

b. Dimensions of Sub-Assembly: Refer to description of subsurface logging sonde.

c. Weight of Density Device: Refer to description of subsurface logging sonde.

d. Special Environmental Requirements: Operating environment - the subsystem is designed to survive the lunar environment as specified in TM 33-13 with the following additional constraints: "...radiation environment allowed at GM counter used in density measurement to be less than 500 gamma quanta/cm^2/sec. and less than 15 electrons (energy > 1 MEV/ cm^2/sec...".

e. Required Orientation: Density device must be decentralized in the borehole such that the source window and detector window are pressed against the borehole wall. If the tool is located above the surface the gamma source window must

be either shielded or directed such that it does not interfere with the surface monitor or the surface density measuring device.

f. Required Knowledge of Orientation: When a measurement is taken the borehole diameter must be known from data taken with caliper.

g. Required Manipulation: Refer to general description of subsurface logging sonde.

h. Sample Preparation Requirements: None.

i. Time per Operating Cycle: 3 minutes.

j. Number of Operating Periods: Refer to description of subsurface logging sonde.

k. Operating Power:

(a) 10 microamps drain (log + monitor).

(b) 800 volts DC of regulated power. Range - 800 ± 100 volts DC. Tolerance - 2% of operating voltage. Ripple - tolerance depends on supply. At 60 cycles, 10 volts ripple is acceptable. In the KC range ripple should be less than 0.1 volt.

l. Data Output:

(a) 2 volt negative pulse, 40 microseconds duration - 50 to 1000 cps.

(b) Load impedance: 500K ohm, range is 100K to 1 megohm.

(c) Measuring range: 0.5 to 4 gm/cc.

(d) Temperature of geiger counters should be known, range ±10°C.

(e) Source - Mercury 203, as big as physically possible, probably around 50 millicuries.

m. Real Time Data Requirements: None.

n. Other Requirements: None.

ACOUSTIC VELOCITY
Subsurface

Location: Explosive source on lunar surface. Acoustic detector in downhole sonde.

a. Description of Method: The integral compressional velocity between the lunar surface and the point of contact of the logging tool to the borehole wall is calculated from measured distances and acoustic travel times measured using a small explosive charge as the acoustic sensor in the downhole unit. The distance from the acoustic sensor to the acoustic source must be known.

b. Dimensions of Subsystem: (Acoustic subsection of sonde) Geophone 1/2 in. diameter by 1/2 in. length, to be mounted on spring and to be in intimate contact with borehole wall. Overall diameter in collapsed condition 7/8 in.; this section to require 2 in. along length of sonde. (See general description of sonde.)

c. Weight: (Acoustic subsection of sonde) 2 oz. total. (Geophone weight, .3 oz.) Acoustic source 12 oz. Source weight may be reduced by combining it with surface velocity source. (See general description of sonde.)

d. Special Environmental Requirements: High temperature limitations on acoustic sources (explosives) same as on

source for surface measurement. Units will function satisfactorily after storage at 350°F for 2 hours, 300°F for 6 hours, 250°F for 24 hours, or 185° for 6 weeks. Will require special attention in thermal radiation requirements.

e. Required Orientation: See general description of subsurface logging sonde.

f. Required Knowledge of Orientation: See general description of subsurface logging sonde.

g. Required Manipulation: See general description of subsurface logging sonde.

h. Sample Preparation Requirements: None.

i. Number of Operating Periods per Lunar Cycle: 10.

j. Time per Operating Cycle: 1 sec. (starting at time of detonation of acoustic source).

k. Operating Power: Firing current for explosive source (located on surface). Assurance of detonation of explosive source during lunar night will require that a minimum of 20 amperes of current be applied, and that this current be available for at least 10 milliseconds. Resistance of the explosive firing element (without attached wires) will be 0.44 ±0.25 ohm. A "time break" signal will be supplied by breaking a wire at time of detonation. Some slight current

(depending on circuit used) will be required. No power is required for acoustic detector.

l. Data Output: Time of travel from source, located at surface, to sonde detector the depth of which will be changed between shots. One miniature geophone (1/2 in. diameter by 1/2 in. length) will be used repeatedly for the various shots. The time break and geophone signal wave-shape will be required as in surface acoustic measurements, but without consideration for the second detector. Signal channel to be similar in all respects to that for the surface measurement, except that travel times as short as 70 microseconds may need to be measured, assuming a maximum velocity of 20,000 ft/sec. source location 1 ft. from the hole, and shallowest measurement at 1 ft. depth. Maximum travel times would be in the same order of magnitude as for surface measurement.

m. Real Time Data Requirements: None. Data storage is acceptable if accurate time measurements are included. Time accuracy required for acoustic measurement is ±5 microseconds, or 5% (whichever is larger), in the uncertainty in time difference between the explosive "time break" and the first arrival acoustic signal. This time difference measurement will range between 70 microseconds and approximately 23 milliseconds.

n. Other Requirements:

(a) Acoustically decouple probe from S/C.

(b) All equipment acoustically quiet during acoustic velocity measurements. Noise with frequencies within the band pass of the acoustic velocity measurements (50 cycles to 5 KC) must be avoided.

(c) Distance between acoustic source and acoustic receiver must be known to within ±5%.

INSTRUMENTATION SUBSYSTEM FOR OPERATING BENEATH LUNAR SURFACE

1. General Function and Dimensions: Covers instrumentation subsystem for downhole use or to be slowly driven into lunar surface. Weight estimates are for instrumentation system only and do not include hole making or driving mechanism. For details on individual measurements see attached description of sonde subsections.

   NOTE: Overall dimensions of downhole logging sonde: Collapsible to 1 in. diameter by 21 in. long (see figure). Acoustic source and shield at surface for 6 shots consists of source holder, 4 in. diameter by 2-1/2 in. high.

2. Environmental Requirements:

   a. Operating Environment: The subsystem is designed to survive the lunar environment as specified in TM 33-13 with the additional constraints as outlined in attached description of sonde subsections.

   b. Non-operating Environment: The subsystem is designed to survive the lunar environment as specified in TM 33-13. Surface explosive source limitations: See attached description of downhole acoustic velocity measurements.

3. Weight Breakdown:

   a. Density - 11 oz.

   b. Acoustic velocity - 2 oz. (plus weight of acoustic source at surface, 12 oz.

   c. Magnetic susceptibility - 4 oz.

   d. Resistivity - 2 oz.

e. Thermal - 10 oz. (includes thermocouples, radiation shields, blackbody, and supports.

f. Caliper - 2 oz.

NOTE: Sonde structure weight (excluding leads and supports from logging sonde to (S/C) - 12 oz.

4. Total Weight:

a. 42 oz. for downhole probe (excluding leads and supports from logging tool to S/C).

b. Acoustic sources and shield - 12 oz.

5. Required Orientation:

a. In consolidated hole: Approximately vertical alignment of logging sonde and variable depth of sonde in hole.

b. In Unconsolidated Material: Approximate vertical alignment of sonde and variable depth of sonde slowly driven into surface.

6. Required Knowledge of Orientation: The distance between the acoustic source (located on surface approximately 1 ft. from hole) and the acoustic detector in sonde, known to ±5%. If hole is required to be normal to local surface within 5°, then only sonde depth and distance from hole to source is required, each to within ±1/2". If hole axis is to be greater than 5° from the local normal, then the azimuthal direction with respect to source location within ±10°, and the angle between the axis of the hole and the local normal to within 5°, need to be known.

7. Operating Power: See attached description of sonde subsections.

8. Time Per Operating Period:

   a. Density - 3 minutes.

   b. Acoustic velocity - 1 second (starting at time of detonation of acoustic source).

   c. Magnetic permeability - time required by S/C equipment to balance bridge and record resistance.

   d. Resistivity - time required by S/C equipment to measure Q of coil.

   e. Temperature - continuous sensor operation, 5 seconds.

   f. Diffusivity - Minimum operating period - 120 minutes.

   g. Caliper - time required by S/C equipment to measure value of resistance.

   h. Radiation background - 3 minutes (surface monitor).

9. Number of Operating Periods: (Based on logging a 6-foot deep hole in 6" steps.

   a. Density - 130

   b. Acoustic velocity - 10

   c. Magnetic susceptibility - 130

   d. Resistivity - 130

e. Temperature: 162 with continuous sampling during day/night and night/day transitions (3 hours centered around sunset and sunrise).

f. Zero readings - 2

g. Diffusivity - continuous recording of temperature of blackbody, 60 min. during heating, and 60 min. after heating - 12.

h. Caliper - 130.

10. Sample Preparation Requirements: None.

11. Manipulation Requirements:

a. Alignment of logging sonde over borehole, raising and lowering of logging sonde in and out of borehole.

b. Placement of acoustic source.

c. Forcing of logging sonde into unconsolidated formation.

12. Data Output: As outlined in attached description of sonde subsections.

13. Real Time Data Requirements: None (see description of acoustic subsection).

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14. Commands required from S/C:

a. In consolidated hole:

(a) Positioning logging sonde over hole.

(b) Lowering and raising of logging sonde vertically within hole.

(c) Triggering of each acoustic source.

(d) Initiation of data sampling and storage.

b. In unconsolidated formation:

(a) Driving sonde into material.

(b) Same as a.(c) and a.(d), above.

15. Operational Sequence:

a. In consolidated Borehole:

(1) Placement of acoustic source.

(2) Orient sonde over hole.

(3) Position sonde in space above lunar surface and below S/C. Record vertical position with respect to lunar surface (tip of sonde is even with surface). Move sonde until electrical coils are 6" from magnetic materials and lunar surface.

(4) Record outputs from following sensors:

(a) Thermocouples and/or thermistors and radiometer.

(b) Magnetic susceptibility.

(c) Electrical resistivity.

(d) Density.

(e) Caliper.

(5) Repeat 14.a.(4) until 10 complete readings have been taken.

(6) Lower sonde until radiometer sensors are approximately one inch below the surface and repeat 15.a.(4)(a) for one reading. This samples borehole temperature as near surface as possible.

(7) Lower sonde three inches and repeat 15.a.(4)(a), one time.

(8) Lower sonde three inches more and repeat 15.a.(4)(a) one time.

(9) Lower sonde to total depth of 12" and repeat 15.a.(4) (a,b,c,d,e) for 5 complete readings.

(10) Lower sonde to total depth in 6" (or 3") steps repeating 14.a.(9), (with due respect to 15.a.(11)).

(11) In the course of 15.a.(10) when acoustic sensor is 1 ft., 2 ft., 3 ft., etc.,belwo the surface (sonde will have reached a total depth ot approximately 30" when acoustic source is 1 ft. below the surface), fire acoustic source and record acoustic signal.

(12) At bottom of hole repeat 15.a.(9) for 5 complete readings, fire acoustic source and record acoustic signal.

(13) Make diffusivity measurement at bottom of hole. Record temperature of blackbody while heating 60 min. and cooling 60 min. While making diffusivity measurements, sample sonde temperature every 30 minutes.

(14) Repeat 15.a.(13) at 1 ft. intervals from the bottom of the hole to the top.

(15) Repeat 15.a.(3) through 15.a.(14) once during lunar day and one during lunar night.

(16) Stop all downhole measurements at day/night or night/day transition minus 3 hours. During this 6-hour transition position tool at 24" or bottom of drilled hole, which ever is least and record temperature continually. Record depth at which temperature is made.

16. Other Requirements:

a. Acoustically decouple sonde from S/C.

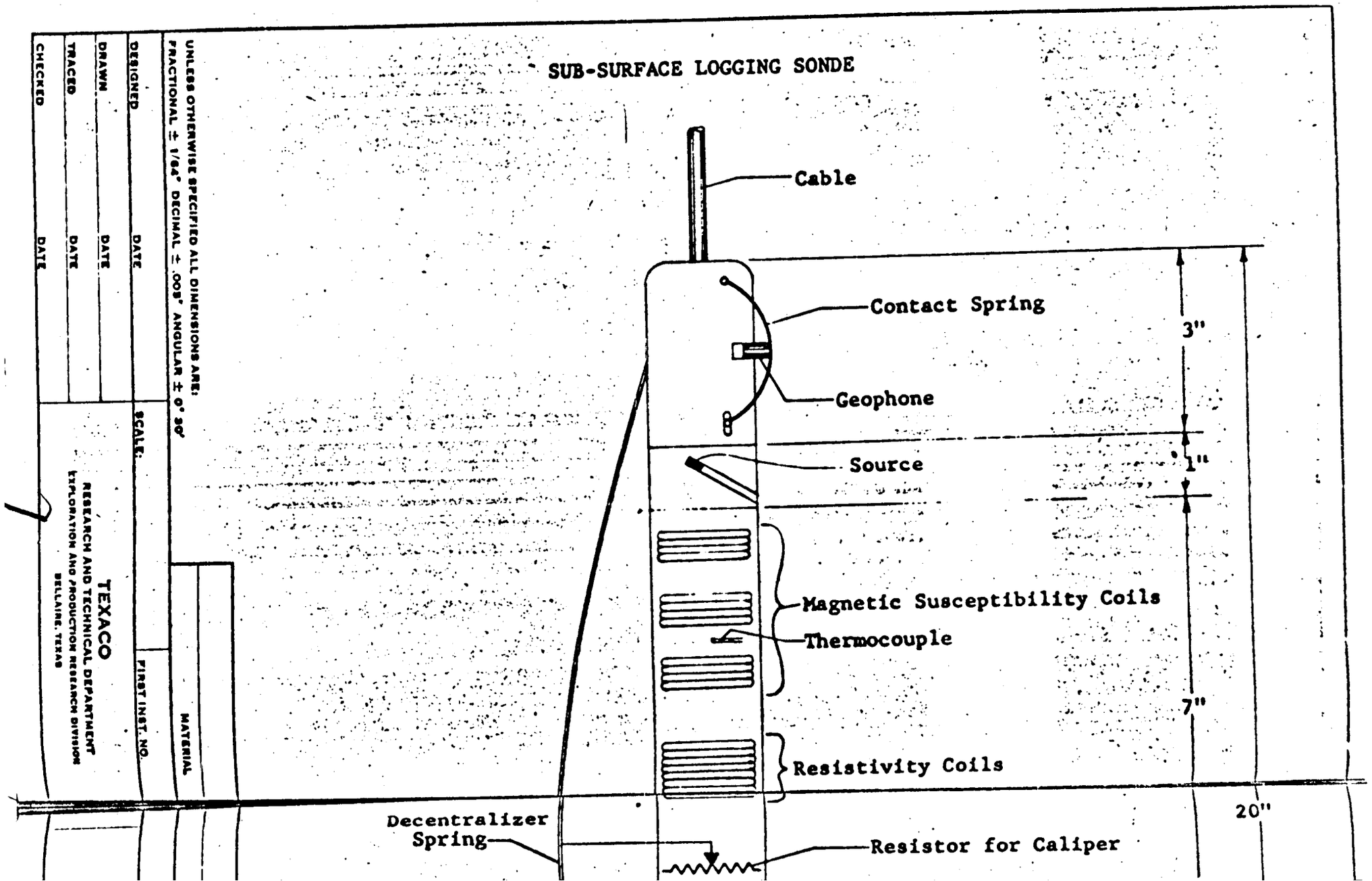
b. Maximum force on slowly driven probe, 50 lbs.

c. All equipment acoustically quiet during acoustic velocity measurement. Noise with frequencies within the bandpass of the acoustic velocity measurements (50 cycles to 5 KC0 must be avoided.

d. Distance between acoustic source and acoustic receiver must be known to within ±5%.

e. Maximum velocity of movement of sonde down borehole after calibration above lunar surface to be less than 1" per sec.

f. Temperature reference to tie all thermocouple reference junctions. Absolute temperature of reference to be known to ±0.5°F. S/C contractor is to provide this reference within the S/C.


SUB-SURFACE LOGGING SONDE
Cable
Contact Spring
Geophone
Source
Magnetic Susceptibility Coils
Thermocouple
Resistivity Coils
Decentralizer Spring
Resistor for Caliper
3"
1"
7"
20"
UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE:
FRACTIONAL ± 1/64" DECIMAL ± .005" ANGULAR ± 0° 30'
DESIGNED
DRAWN
TRACED
CHECKED
DATE
SCALE:
FIRST INST. NO.
MATERIAL
TEXACO
RESEARCH AND TECHNICAL DEPARTMENT
EXPLORATION AND PRODUCTION RESEARCH DIVISION
BELLAIRE, TEXAS

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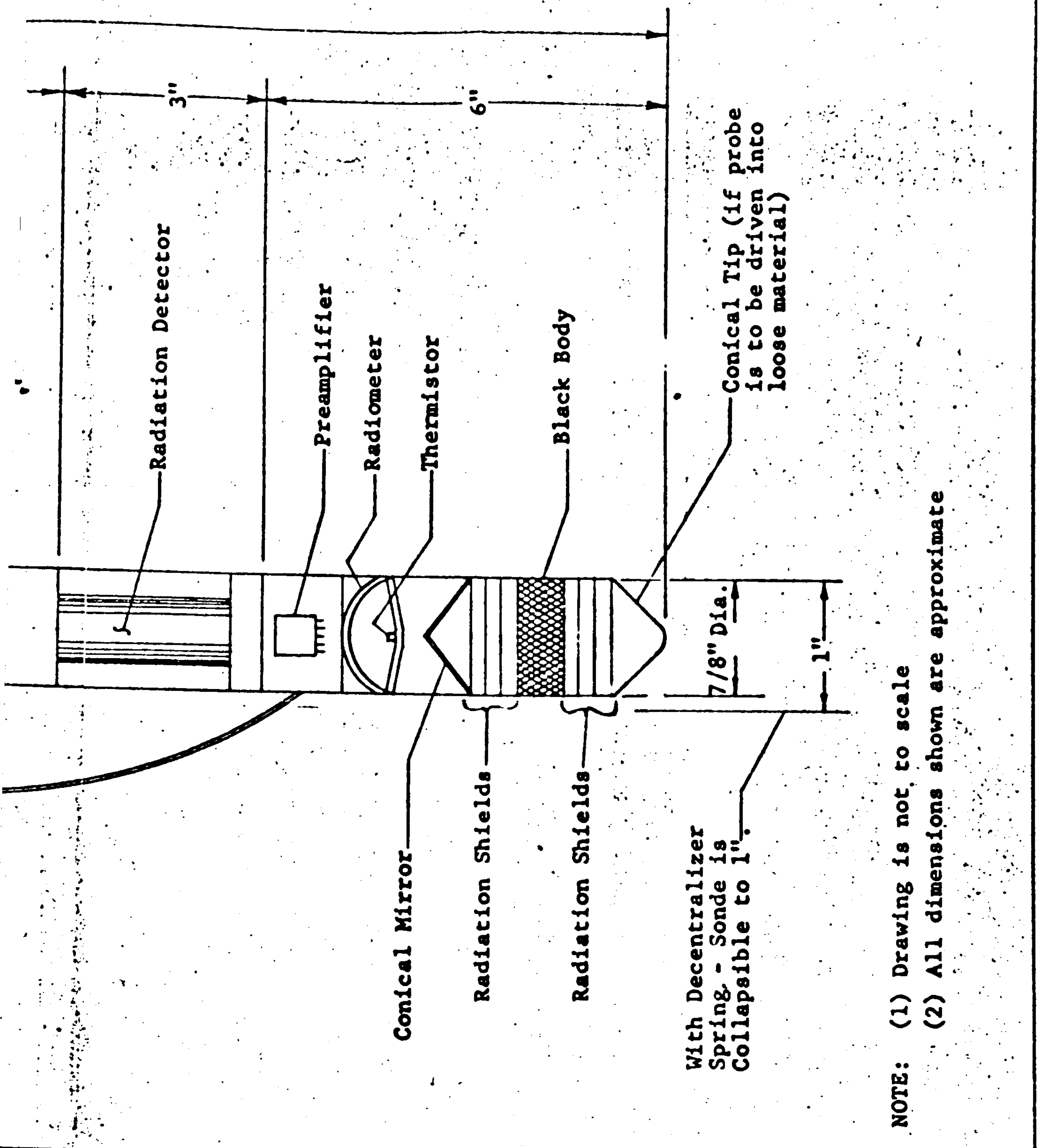

SIZE	QUANT.	LET.	REVISIONS	DATE	BY

CORRECT FOR INST. NO.	SUPERSEDED BY	SUPERSEDES

SUB-SURFACE LOGGING SONDE
FIGURE 1

ASSEMBLY

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